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# Trawl and acoustic survey in southern Bonavista Bay – Observations on demersal distribution of Atlantic cod

John T. Anderson and Edgar L. Dalley

Department of Fisheries and Oceans
P. O. Box 5667
St. John's, NF
A1C 5X1

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**Abstract**

A trawling and acoustic survey was conducted throughout southern Bonavista Bay in December 1999. The most abundant species caught in the trawl was Atlantic cod (*Gadus morhua*), followed by American plaice (*Hippoglossoides platessoides*) and Arctic cod (*Boreogadus saida*). Atlantic cod were predominantly juveniles < 40 cm length caught most abundantly in water depths < 125 m. The largest catch of juvenile cod was 10,509 for a 10 minute tow, while the largest catch of large juvenile and adult cod was 652 for a 10 minute tow. Water temperatures ranged from approximately 0 °C at 100 m to 3.5 °C at the surface. Minimum water temperatures of –1.5 °C occurred at approximately 175 m, rising to 0 °C at 300 m in the deep trenches. Acoustically, small juvenile cod were observed throughout the survey area at depths of < 100 m. One concentration of large, adult cod, was located at depths < 30 m within a narrow channel in Southern Bay, inside of Sandy Point. These cod were relatively good condition, although all stomachs were empty. No fish concentrations were observed in the deep trenches (i.e. 200-300 m depth). A diurnal pattern was observed, where cod lay near, or on, the seabed during daytime and rose into the water column at night. This diurnal pattern indicates that night time trawling will be biased low due to fish occurring above the trawl headline, while daytime acoustics will be biased low by cod lying within the acoustic dead zone. Therefore, design of an inshore survey must address diurnal behaviour in Atlantic cod.

**Résumé**

Un relevé au chalut et au sonar a été effectué dans l'ensemble de la partie sud de la baie Bonavista en décembre 1999. L'espèce la plus capturée au chalut a été la morue de l'Atlantique (*Gadus morhua*), après quoi venaient la plie canadienne (*Hippoglossoides platessoides*) et la morue polaire (*Boreogadus saida*). Les morues de l'Atlantique étaient surtout représentées par des juvéniles de moins de 40 cm de longueur généralement capturés à des profondeurs inférieures à 125 m. La plus importante capture de juvéniles a été de 10 509 poissons en un trait de 10 minutes et la plus importante capture de juvéniles de grande taille et d'adultes a été de 652 poissons en un trait de 10 minutes. La température de l'eau variait de 0 °C environ à 100 m à 3,5 °C à la surface. Une température minimale de l'eau de –1,5 °C a été notée à 175 m environ mais elle s'élevait à 0 °C à 300 m dans les fosses profondes. Des morues juvéniles de petite taille ont été observées par méthode acoustique dans toute la zone du relevé à des profondeurs de moins de 100 m. Une concentration de morues adultes de grande taille a été décelée à des profondeurs de moins de 30 m dans un chenal étroit de Southern Bay, à l'intérieur de Sandy Point. Ces morues étaient dans une condition relativement bonne, mais tous les estomacs étaient vides. Aucune concentration de poissons n'a été aperçue dans les fosses profondes (200-300 m). Un régime diurne a été décelé, les morues se trouvant à proximité du fond, ou sur le fond, pendant le jour et dans la colonne d'eau pendant la nuit. Ce régime diurne fait que le chalutage de nuit est biaisé à la baisse par la présence de poissons au-dessus du chalut, le relevé acoustique de jour étant biaisé à la baisse par la présence de morue dans la zone acoustique morte. Cependant, la conception d'un relevé côtier doit donc tenir compte du comportement diurne de la morue de l'Atlantique.

## Introduction

In the 1990's, Atlantic cod of the northern stock (NAFO Div. 2J3KL) have been distributed primarily within the inshore bays along the northeast coast of Newfoundland (Dalley and Anderson 1997). These bays are characterized by an irregular coastline often populated by many islands and with sounds that extend from deeply landward out to the open ocean dominated by the inshore branch of the Labrador Current. Depths range from the coastline to shallow inshore banks that reach 20 m depth, down precipitously to depths that can exceed 300-500 m. The bottom relief can be highly irregular and even low relief bottoms can be dominated by rough, untrawlable seabed.

Historically, these inshore areas have been the predominant refugia for demersal juvenile cod (Lear et al. 1980, Dalley and Anderson 1997, Anderson and Gregory 2000). Juvenile cod, particularly less than 30-40 cm length, are known to utilize seabed habitats to increase survival (Gotceitas and Brown 1993, Gotceitas et al. 1995, Tupper and Boutilier 1995, Gregory and Anderson 1997). Inshore, juvenile cod exhibit strong diurnal behaviour (Keats 1990, Keats and Steele 1992, Methven and Bajdik 1994, Anderson and Dalley 1995) that does not appear to occur as strongly at deeper depths offshore (Dalley and Anderson 1997). Diurnal behaviour also has been observed for adults at shallow depths in Bonavista Bay, where they were distributed close to the bottom during day and dispersed off the bottom at night (Anderson et al. 1999).

Previously, we proposed that surveying fish distribution and abundance in the inshore area requires innovative techniques that combine high resolution acoustic technology with trawls adapted to sampling relatively small areas over rough bottom (Anderson and Dalley, Unpubl. Report). During recent years, we have been developing acoustic and trawling techniques to sample the inshore environment of southern Bonavista Bay. In late November and early December of 1999 we carried out our first attempt at conducting an acoustic/trawl survey in southern Bonavista Bay. Here we report the preliminary results from the survey.

## Methods

A modified Yankee shrimp trawl (MYST) fit with Scanmar sensors was towed for 10 minutes, or less, from the RV Shamook. This trawl has a 60 foot headline and was fit with a modified footgear employing small rubber disks 4 x 8 inches in dimension. The net was constructed of polyethylene with 40 mm mesh size in the wings, bellies and codend with a 12.7 mm liner in the codend. During fishing, the trawl dimensions averaged 12.7 m wide by 2.0 m high. The survey design searched for trawlable bottom within each of the areas, or strata, selected within southern Bonavista Bay, attempting to fish two or more sets within 50 m depth strata in each area (Figure 1). The shallowest depth range was 0-50 m and the deepest was 300-350 m. The eight strata conformed to geographical areas: Newman Sound; Clode Sound; Chandler Reach; Goose Bay; Sweet Bay; Southern Bay; Plate Cove Coast; Swale Tickle. The survey was carried out from November 26 to December 2 during daylight hours. All biological samples were

processed aboard the RV Shamook, including length, weight, sex, maturity and stomach contents. Otolith samples were collected to determine age at a later time.

A 120-38 kHz dual frequency DT6000 digital echosounder was used, side-towed at approximately 3-5 m depth from the RV Shamook. The digital echosounder operates in dual-beam (120 kHz) and split-beam (38 kHz) modes, with all raw data being saved. The survey design consisted of randomly selected cross-channel transects, designed to begin and end in shallow water at the coastline, or at 300 m in deep water (Figure 1). Sampling speed varied between 3-5 knots with care taken to minimize acoustical ship noise by altering the propeller speed and pitch. The acoustic survey was conducted from December 3-13, 1999 from 8 AM to 8 PM each day. Directed fishing was conducted during the acoustic portion of the survey using hand held and automatic jiggers.

Temperature, salinity and density were sampled at each trawl location using a Seabird SBE-19 CTD.

**Results**

The proportion of trawl sets was greater for depths < 100 m (58%) than from 100-350 m (Figure 2). However, we achieved a remarkably wide geographical distribution of trawl sets throughout the survey area over a broad range of depths.

Temperature averaged 3.5 °C in surface waters and declined steadily below 10 m depth reaching minima of < -1.5 °C at approximately 175 m depth (Figure 3). In deeper waters, which occurred within the sounds, water temperature warmed up again to approximately 0 °C. There was a low degree of variability in temperature throughout the survey area.

A wide range of species were caught with the bottom trawl, where Atlantic cod was the most abundant (n=9956, not standardized), followed by American plaice (n=5760). Other fish species caught included Arctic cod (n=1739), capelin (n=331), herring (n=193) and Greenland halibut (n=156) as well as many non-commercial species.

Atlantic cod ranged in length from 60 mm to over 800 mm (Figure 4). The catches were dominated by juvenile cod < 400 mm length, where the dominant mode occurred at 140-180 mm length and a second mode occurred at 80-120 mm. These modal size ranges relate to one year old cod and young-of-the-year (0-group) cod, respectively, based on previous studies of juvenile cod (Dalley and Anderson 1997). Therefore, 1998 was the dominant year-class caught in the trawl survey. For the larger cod, the dominant lengths ranged from 50 to 75 cm (500 – 750 mm) with no one length group dominating the length frequency distribution. The large cod were predominantly adults.

The largest catch of cod was 10,509 per standardized 10 minute tow, caught in Southern Bay north of Princeton (Figure 5). These cod were predominantly small juvenile cod (i.e. < 40 cm). The largest catch of large cod occurred in Goose Bay near Jamestown, where 652 cod per standardized 10 minute tow were caught (Figure 5). Geographically, there was no particular pattern to the catches of cod, where large and small, or zero, catches

occurred in close proximity. There was a negative relationship where cod abundance decreased with increasing depth, explaining 46% of the variation in cod catches (Figure 6).

Acoustically, cod were observed throughout the survey area although the acoustic distribution of small cod near the bottom was heterogenous. Overall, the distribution of acoustic targets largely reflected the distribution in the trawl catches, where most acoustic targets occurred less than 100 m depth. No fish concentrations were observed acoustically in the deep trenches of the different sounds, to approximately 300 m depth. During daytime these cod occurred near the seabed but were observed at dusk rising off the bottom occurring well up into the water column (Figure 7). As most of the acoustic survey was conducted during daylight, observations of cod at night were limited to the period around dusk.

Acoustically, we encountered only one concentration of large cod in very shallow water at the extreme limit within Southern Bay (Figure 5). These cod were encountered at depths < 30 m to approximately 15 m where the bay had narrowed considerably. The cod were tightly grouped together on the bottom during day (Figure 8a) but with dusk they began to disperse off the bottom (Figure 8b). During daytime, maximum cod concentrations were approximately 1 fish $m^{-3}$. These fish were all sexually mature, ranging in length from 50 to 80 cm with an average length of 65.0 cm and weight of 2.85 kg (Figure 9). Condition (Fulton's K Index) averaged 1.01, ranging from 0.80 to 1.20 based on round weight. All stomachs were empty and, therefore, did not contribute fish weight.

**Discussion**

It is difficult to assess the abundance of cod sampled in this survey using the MYST trawl based on one year of data. Surveys were carried out in December and January at fixed stations inshore and offshore 1992-1994 using a Campelen 1800 modified shrimp trawl (Dalley and Anderson 1997). Over these three years the catch rate of cod inshore in 3L averaged 199 fish per 30 minute tow. By comparison, the average catch rate was 1181 fish per tow in Bonavista Bay in 1999 using the MYST trawl and adjusting the catch rate to Campelen equivalent units in terms of sampling effort. This much higher catch rate may result from a greater catchability for juvenile cod by the MYST trawl, compared to the Campelen. The MYST trawl is designed to sample very close to the bottom and does not hop over rough terrain, as is the case using rockhopper gear on the Campelen. However, we note that the abundance of 0-group (1999 yc) cod was lower than one year old cod (1998 yc) in the MYST trawl catches. This contrasts with 0-group estimates of year-class strength, where the 1999 year-class was higher than the 1998 year-class (Dalley et al. MS2000, Gregory et al. MS2000). This suggests that the catchability of demersal 0-group cod was relatively low in the MYST trawl. A similar low catchability for demersal 0-group cod was made using the Campelen trawl over three years (Dalley and Anderson 1997). Therefore, the much higher catch rate of cod in Bonavista Bay in 1999, using the MYST trawl compared to the Campelen trawl 1992-1994, may also be due to higher abundance.

Our conceptual model of cod distributions in southern Bonavista Bay is that juvenile cod occur throughout the area at depths less than 100-200 m and that over wintering concentrations of adult cod occur in the deep trenches > 200 m where water temperatures are warmer. Historically, cod have been reported to overwinter in southern Bonavista Bay and spawn in the spring, from mid-April to mid-July, with spawning locations generally in the deepwater trenches (Potter 1996). We did not encounter any large concentrations of adult cod in southern Bonavista Bay in our survey. If such concentrations still occur then it is possible fish move into the area during mid to late winter prior to spawning.

Higher catches of cod (> 20/tow) occurred at depths less than approximately 125 m. Water temperatures throughout the survey were > 0°C at water depths less than approximately 80-125 m. This suggests that the warmer thermal habitat of shallower waters was preferred by juvenile cod and, in particular, by the adult cod sampled in < 30 m water depth in Southern Bay. It is possible that as waters continued to cool into the winter period that these shallow areas may become less suitable habitat for Atlantic cod.

Diurnal differences in distribution were also observed in December 1998 (Anderson et al. 1999). The strong day night differences exhibited by cod, both juveniles and adults, has important implications for survey design within the inshore. Cod which rise significantly off the seabed at night would result in an underestimate of night trawl catches compared to daytime. Conversely, cod lying on, or close to, the seabed cannot be detected acoustically. In addition, very tight concentrations, such as we observed for adult cod in Southern Bay, minimize the detection of individual targets and can saturate the acoustic signal. Therefore, trawling may be best conducted during daytime while acoustic surveying may best be done at night.

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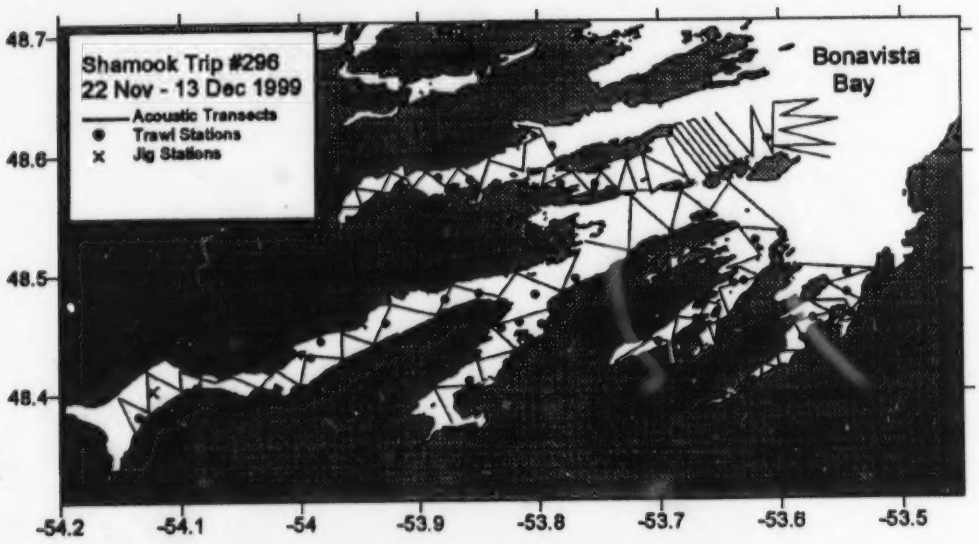


Figure 1. Trawl locations and acoustic survey tracks in southern Bonavista Bay, November 22 to December 13, 1999. Jigging locations are also indicated.

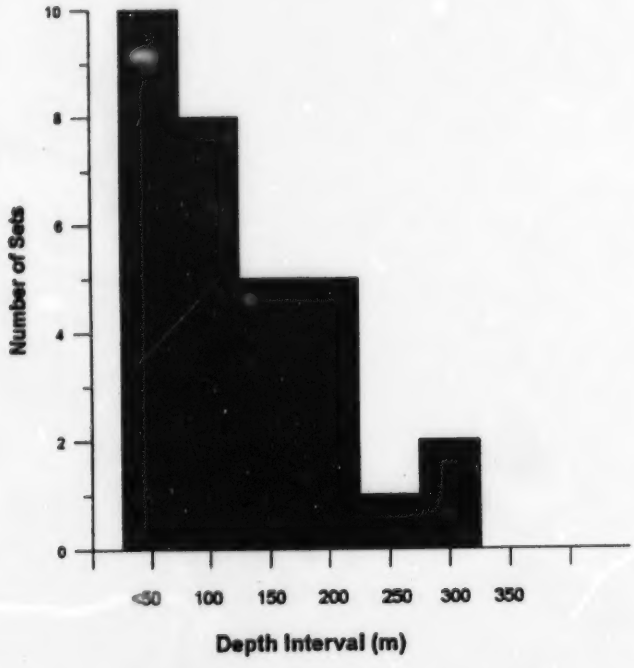


Figure 2. Depth distribution of trawl sets stratified in 50 m depth intervals throughout southern Bonavista Bay.

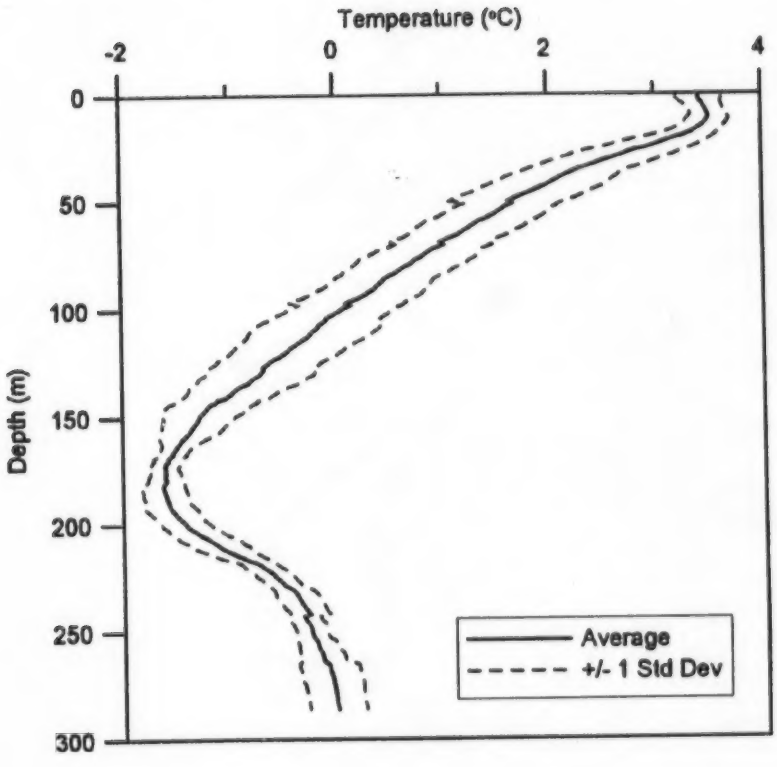


Figure 3. Mean temperature (°C) profile (± 1 std) measured at the 31 trawl locations in southern Bonavista Bay.

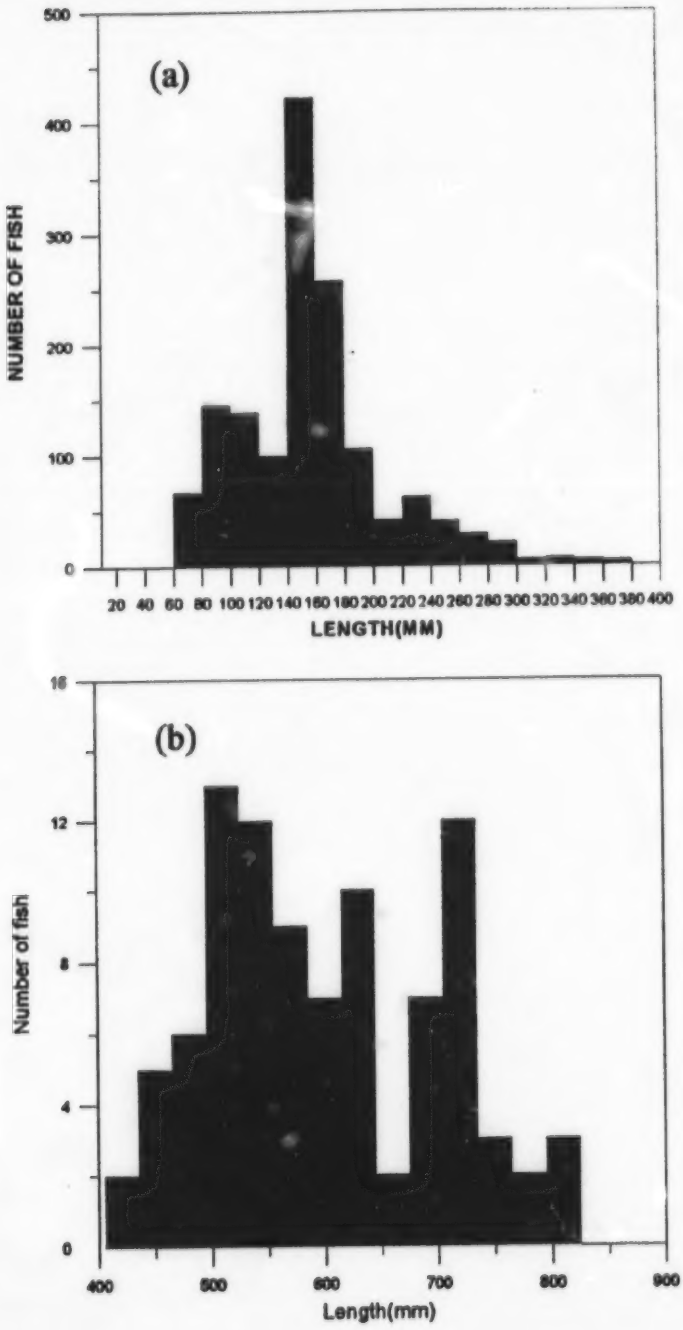


Figure 4. Length frequency distributions of (a) juvenile cod < 40 cm length and (b) large juvenile and adult cod sampled by the trawl in southern Bonavista Bay.

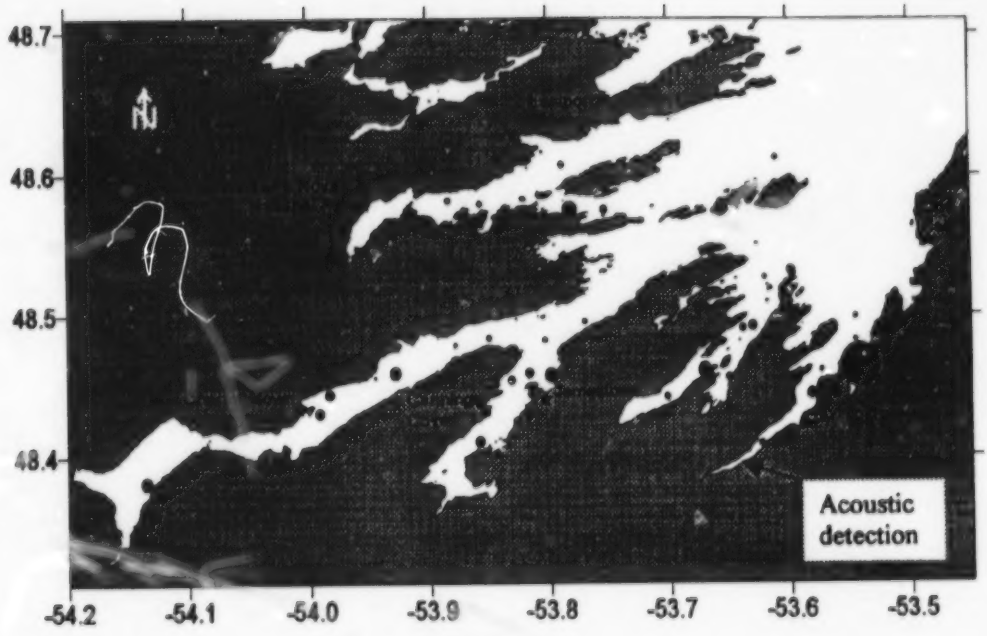


Figure 5. Distribution of Atlantic cod in southern Bonavista Bay based on the trawl survey. The symbols represent catches from 1 to 10,500 fish per 10 minute tow, scaled linearly. The arrow south of Princeton ("Acoustic detection") indicates the only location of large cod detected acoustically.

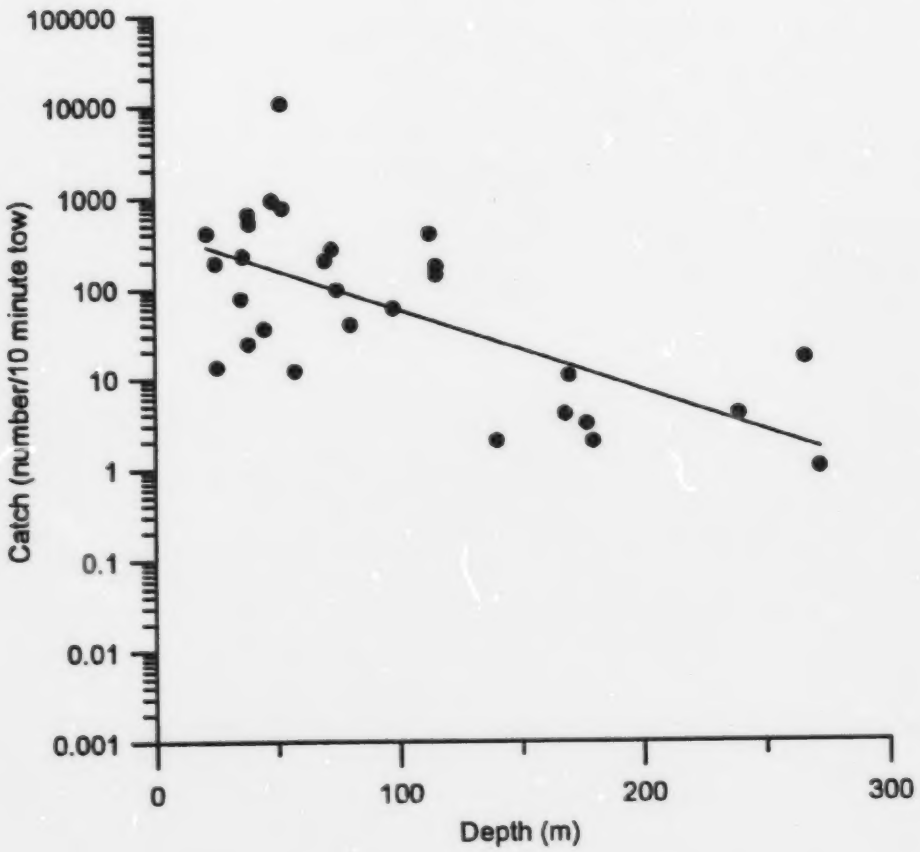


Figure 6. Distribution of cod trawl catches in relation to the depth of tow in southern Bonavista Bay.

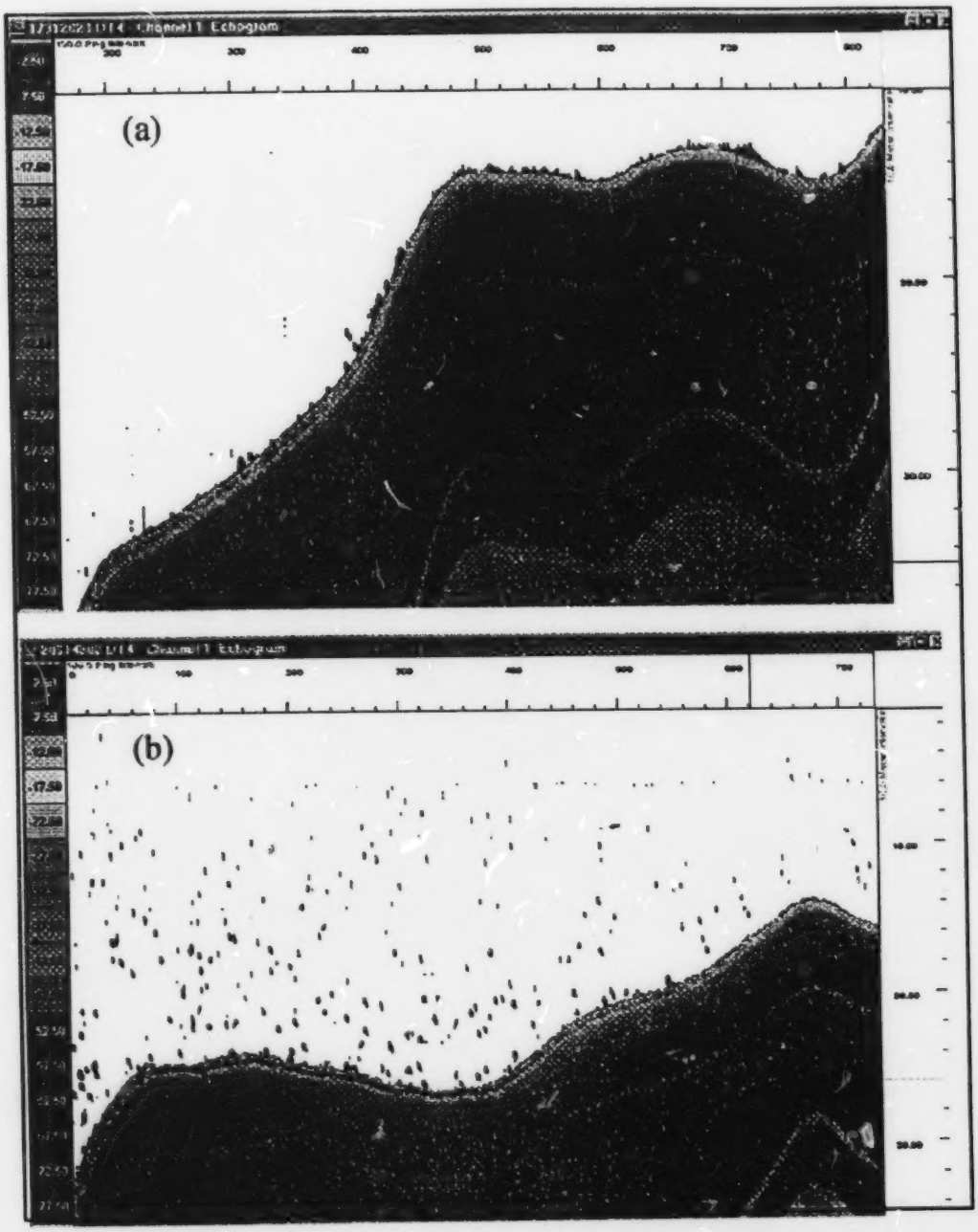


Figure 7. Acoustic distribution of juvenile cod (a) near the bottom during day and (b) dispersed throughout the water column at night, in Inner Clode Sound.

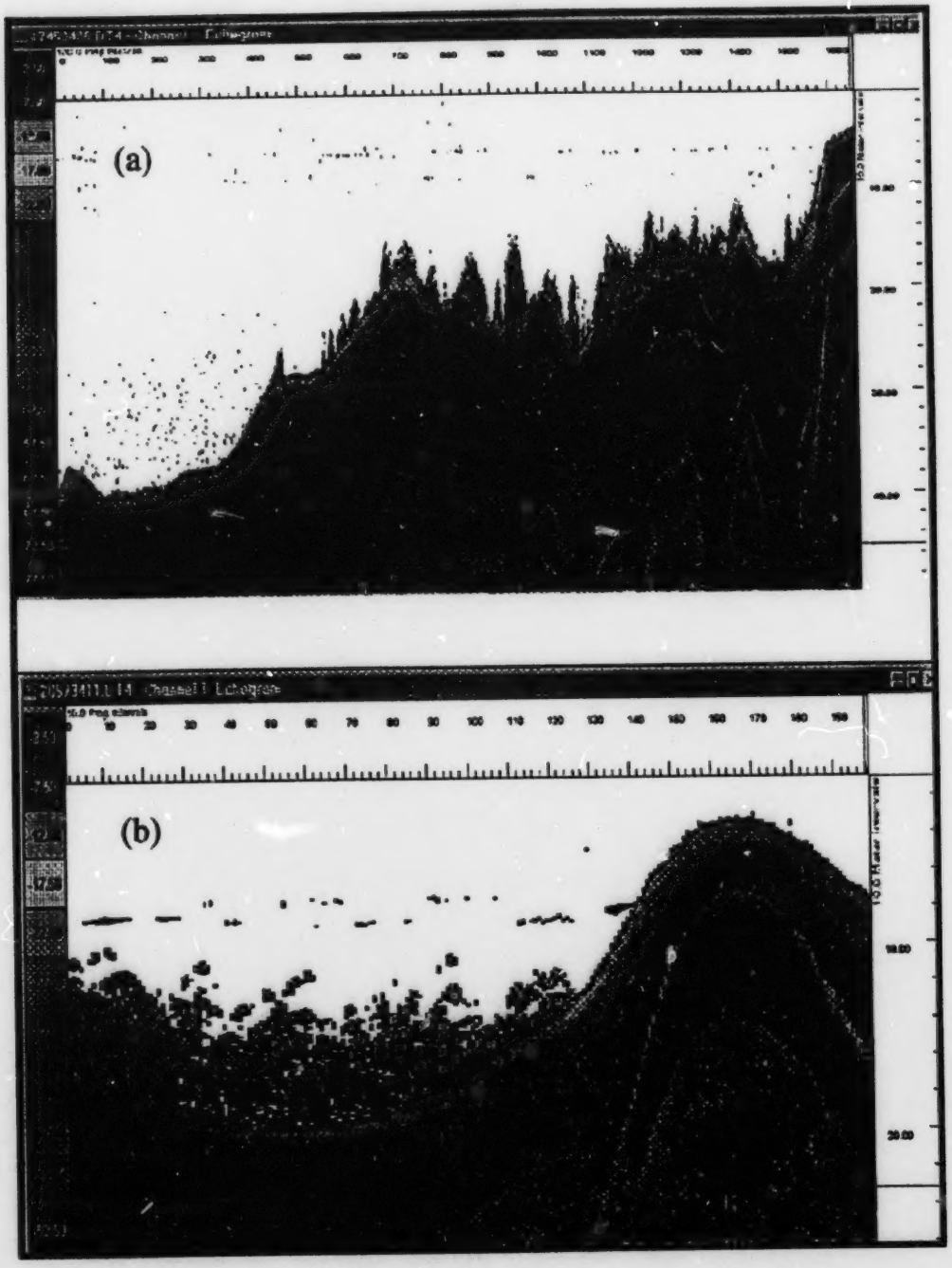


Figure 8. Acoustic distribution of large cod surveyed within Southern Bay, Bonavista Bay (a) surveying along the bay axis from deep to shallow and (b) cross axis at 20 m.

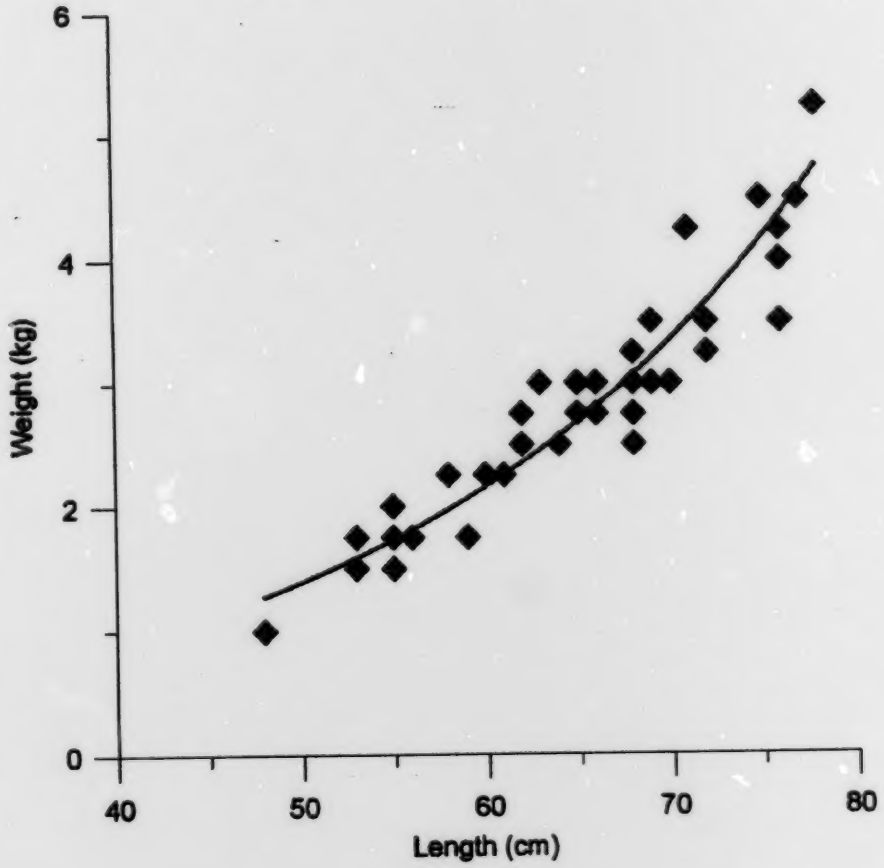


**Figure 9. Length-weight relationship for large cod sampled in Southern Bay, Bonavista Bay.**